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TEMPERATURE SURVEY OF KITTITAS COUNTY, WASH.

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[Weather Bureau, Pomona, Calif., February 1936]

The history of fruit growing in western United States is replete with examples of the planting of orchards in wrong locations. Poor soil, insufficient rainfall or irrigation water, excessive wind, poor drainage, and similar factors all have had their part in necessitating the eventual abandonment of thousands of acres of fruit trees, with a resulting loss of millions of dollars invested; but probably the greatest loss has been caused by the planting of orchards in areas of excessive frost hazard. Although the existence of so-called thermal belts on hillsides has been recognized since at least before the middle of the last century, and the mechanical aspects of air drainage have long since been accurately analyzed, the frost hazard has until very recently been almost completely ignored in planting orchards. Orchards planted in frost pockets usually lead to the bankruptcy of a long succession of owners before they are finally abandoned.

Temperature surveys have been conducted in old-established fruit-growing districts on the Pacific Coast for many years in connection with the Weather Bureau's Fruit-Frost Service, but the application of the information obtained has been limited to delineating areas in which artificial frost protection is needed, or to demonstrating the advisability of abandoning individual orchards in which the frost hazard is hopelessly great.

Irrigation development of the Yakima River Valley in Kittitas County, Wash., began in 1888, with the construction of the "Town Ditch", which furnished water for land on the valley floor north of the river. The West Side Canal, constructed in 1891, and the Cascade Canal, constructed in 1904, increased the total irrigated area to approximately 26,000 acres, and brought water to practically all of the good land at lower levels in the district. Scattered orchards were planted throughout most of the valley in the early days, but at present only a small acreage immediately below the old Cascade Canal on the southern edge of the valley remains. Excessive frost hazard has caused the removal or abandonment of the rest.

When the United States Reclamation Service began to plan an extensive new irrigation system to bring water to 72,000 acres of hillsides and benches high above the valley floor, at a cost of $9,000,000, practically doubling the area under irrigation, it was decided to take all possible steps to insure the success of the individual farmer in taking up land under the new project. Messrs. Strahorn and Kocher of the United States Department of Agriculture made a very accurate and detailed soil survey of all the land, making use of extensive borings and test pits to determine the different classes of land and the soil types; and the Weather Bureau was requested to conduct a 5-year temperature survey. Kittitas County cooperated in the temperature survey work, purchasing the instrument shelters and carrying a portion of the annual expense.

DESCRIPTION OF THE DISTRICT

Kittitas County is located near the geographical center of the State of Washington. The irrigated area, lying along the Yakima River on the eastern slope of the Cascade Mountains, is a basin about 25 miles long and 11 miles wide, extending in a northwest-southeast direction. It is surrounded by hills that are from 3,000 to 4,000 feet in elevation. The Yakima River leaves the basin through a deep and narrow canyon about 10 miles south of Ellensburg. Most of the soil in the irrigated area is of deep volcanic ash, but there are large areas of stony land, with soil too shallow for orchards. The valley floor, watered by the old irrigation systems, is given over at present almost entirely to dairying and the growing of grain and forage crops. Irrigation water comes from the Cascade Mountains and is stored in three large artificial lakes near the headwaters of the Yakima River, constructed at a cost of an additional $2,000,000. The valley naturally is semidesert, the annual rainfall at Ellensburg averaging about 9 inches.

The land under the new Reclamation Service project, on which the temperature survey was conducted, all lies on moderate to steep slopes or benches some distance above the valley floor. At the time the temperature survey was begun in 1931 the area had never been cultivated, and was covered with a heavy growth of sagebrush. Roads were few and poor, and some difficulty was experienced in devising means to reach the various survey stations to make the temperature readings. During the 5-year period, however, most of the land was sold or homesteaded, sagebrush was cleared, the land cultivated, and good main roads were constructed. During the last two seasons of the survey a large portion of the land was planted to grain, alfalfa, seed peas, and other crops.

HOW THE SURVEY WAS MADE

The area to be reclaimed by the new irrigation project was too large to be covered adequately by the few temperature stations for which equipment was available, and after a conference with Reclamation Service officials all but the areas having the best soil conditions were eliminated. As the survey progressed, stations at which it became evident that temperature conditions were unsuitable for the growth of anything but the hardier crops were eliminated, and the instrumental equipment moved to new locations which it previously had not been possible to cover adequately. Twenty-nine temperature stations were kept in operation throughout the period from about March 20 to May 20, during the five spring seasons from 1931 to 1935 inclusive, each equipped with a standard fruit-region instrument shelter, minimum thermometer and thermograph. The minimum thermometer was approximately 4½ feet above the ground at all stations.

Station locations were selected with great care, keeping in mind areas already known to be marginal due to excessive frost hazard. Topographically similar areas, such as are to be found on the north side of the district, required relatively few stations, while topographically irregular areas, such as the Edgemont and Badger Pocket sections, with good soil, were allotted a greater number of stations per unit of area. Since little of the surveyed area was fenced, it was necessary to protect the instrument shelters from injury by stock by building barbed wire inclosures. A trip of 140 miles was required to visit all the stations.

With very few exceptions, caused by emergencies, minimum thermometers at all the survey stations were read on each day following the occurrence of a temperature of 32°, or lower, at any station. Thermograph records were checked for both time and temperature at each reading. On the few dates when it was not possible to visit all the survey stations, the minimum temperatures were taken from the thermograph records.

One station, number 1, was established in an abandoned apple orchard on the valley floor as a check on temperature conditions definitely known to be unsatisfactory for fruit production. Station number 3 was located in another apple orchard on a slight slope a few feet higher than the valley floor in the southwestern part of the district, which had not been abandoned but which production records showed to be submarginal owing to excessive frost hazard. Station number 2 was located in an apple orchard higher on the slope, with better air drainage, which records showed to have been consistently profitable. A comparison of temperature records obtained at other survey stations on the project with those obtained at stations 1, 2, and 3, should make possible a definite classification of different areas with regard to their suitability for apple growing (see tables 1 and 2).

Throughout the period of the survey, complete daily observations of current temperature, wind direction and velocity (estimated), amount, type, and direction of clouds, maximum and minimum temperature, dewpoint, and relative humidity, were made at station 1 daily at 4:40 p. m., Pacific time, the regular time of making evening observations at all Weather Bureau stations in the country. In addition to their climatological value, these records will be invaluable in case a minimum-temperature forecasting service for the district is undertaken at any future time.

The locations of all the temperature survey stations in the district, as well as the Ellensburg cooperative station, are shown in figure 1. As detailed a description of the various locations as it is possible to make is given below.

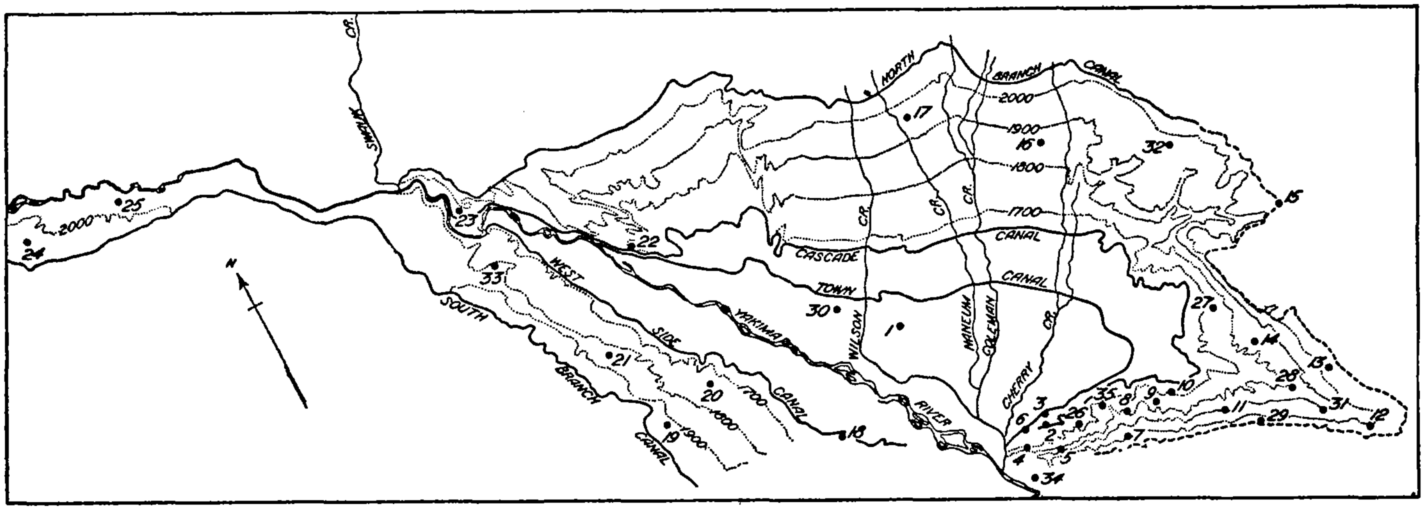

FIGURE 1.

DESCRIPTION OF TEMPERATURE SURVEY STATIONS, KITTITAS COUNTY, WASH., 1931–35

Station 1: Alva Bull Lone Star Ranch, 1¼ miles east, ¾ mile south of Ellensburg. Shelter in small home orchard 40 feet northwest of tenant house. Slight northeast to southwest slope. Soil good. Elevation 1,545 feet.

Station 2: A. J. Seible commercial orchard, Edgemont-Thrall district. The shelter in southwest portion of orchard 500 feet south-southwest of Seible residence. Moderate southwest to northeast slope. Soil excellent. Elevation 1,628 feet. (This station, located in what is known to be a profitable orchard, was established to furnish a comparison with other prospective orchard land in the district.)

Station 3: Shelter located 200 yards south-southeast of Eugene Wilson residence, Thrall, in commercial orchard 100 feet west of northeast corner of northwest quarter of northwest quarter of sec. 33, T. 17 N., R. 19 E. Slight north to south slope on bottom of considerable draw. This station established to furnish basis for comparison of other localities in the district with one where conditions are thought to be marginal. Soil very good. Elevation 1,538 feet.

Station 4: Edgemont-Thrall 80 feet west and 220 feet south of the northeast corner of the northwest quarter of the southwest quarter of sec. 32, T. 17 N., R. 19 E. Steep south-southwest to north-northeast slope, soil excellent. Elevation 1,775 feet.

Station 5: Edgemont-Thrall, 500 feet east, 350 feet south of southwest corner of sec. 33, T. 17 N., R. 19 E. Steep south to north slope, soil excellent. Elevation 1,828 feet.

Station 6: Edgemont-Thrall, 50 feet south of county road, 200 feet east of Alva Bull farmhouse, northeast quarter of northwest quarter of sec. 32, T. 17 N., R. 19 E. Slight south to north slope, soil excellent. Elevation 1,493 feet.

Station 7: Edgemont, 200 feet west, 200 feet south of center of sec. 3, T. 16 N., R. 19 E. Soil excellent, moderate south to north slope. Elevation 1,973 feet.

Station 8: Edgemont, station 400 feet east and 150 feet north of southwest corner of sec. 35, T. 17 N., R. 19 E. Soil excellent, steep west-southwest to east-northeast slope. Elevation 1,818 feet.

Station 9: Station located 75 feet east of Lawrence Gehlen farmhouse or 100 feet southeast of southeast corner of sec. 35, T. 17 N., R. 19 E. Gentle slope from south-southwest to north-northeast with good soil. Elevation 1,741 feet.

Station 10: Edgemont, 200 feet east, 100 feet south of northwest corner of sec. 1, T. 16 N., R. 19 E. Gentle southwest to northeast slope. Soil excellent. Elevation 1,694 feet.

Station 11: Edgemont-Badger Pocket, 500 feet east, 500 feet south of northwest corner of sec. 7, T. 16 N., R. 20 E. Soil very good, moderate south-southwest to north-northeast slope. Elevation 1,903 feet.

Station 12: Badger Pocket, 800 feet east, 500 feet south of northwest corner of sec. 22, T. 16 N., R. 20 E. Soil good, gentle local slope from southwest to northeast. Elevation 2,013 feet.

Station 13: Badger Pocket, 1,000 feet west, 150 feet south of center of sec. 10, T. 16 N., R. 20 E. Soil fair, gentle and extensive east to west slope. Elevation 2,035 feet.

Station 14: Badger Pocket, 400 feet north of southwest corner of sec. 33, T. 16 N., R. 20 E. Soil good, local moderate east to west slope. Elevation 1,851 feet.

Station 15: Johnson Creek Canyon, 2,000 feet northeast of Milwaukee Railroad trestle, about 5 miles east-southeast of Kittitas. Soil very good, station located on bottom of small draw with slight east to west slope. Elevation 2,000 feet.

Station 16: Snodgrass farm, 1 mile east and 2½ miles north of Kittitas. Shelter situated 50 feet southeast of house. Soil fair with extensive gentle northeast to southwest slope. Elevation 1,880 feet.

Station 17: Barre farm, 4 miles North of North Central Highway and 3½ miles east of Ellensburg. Station in very small old orchard, 100 feet southwest of house. Soil fair, extensive gentle north to south slope. Elevation 1,970 feet.

Station 18: McNeal station. Section corner of secs. 15, 16, 21, and 22, T. 17 N., R. 18 E. Soil excellent, moderate to steep slope from southwest to northeast. Elevation 1,751 feet.

Station 19: Catlin farm, 6 miles west and one-half mile south of Ellensburg at end of county road, about 1,000 feet east-southeast of Catlin house. Soil good, slope generally moderate from west to east. Elevation 1,916 feet.

Station 20: Prater farm, 4¾ miles west of Ellensburg on gravel road, 200 feet west of barn on south side of road. Sec. 6, T. 17 N., R. 17 E. Soil good, general moderate southwest to northeast slope. Elevation 1,741 feet.

Station 21: Kilmore farm, 6½ miles west, 1¾ miles north of Ellensburg, 300 feet east of farmhouse in alfalfa field. Soil good with rather irregular moderate slope from southwest to northeast. Elevation 1,832 feet.

Station 22: Dry Creek station, 1,500 feet south, 1,500 feet east of the southwest corner of sec. 7, T. 18 N., R. 18 E. Soil excellent, station on southwest to northeast steep slope representing a rather limited area. Elevation 1,787 feet.

Station 23: Hayward "Flat", a bench 1,400 feet west and 1,280 feet north of southeast corner of sec. 28, T. 19 N., R. 17 E. Soil very good, surrounding territory extremely irregular as to soil and topography. Conditions at this station are representative of numerous other "flats" in the general vicinity. Shelter exposed approximately one-fourth mile west of Walter Hayward farmhouse. Elevation 1,826 feet.

Station 24: Peoh Point station, in old Boedcher home orchard 50 feet northeast of road fork, 1½ miles south of Cle Elum. Soil very good, variable moderate slope, from southwest to northeast at station. Elevation 2,029 feet.

Station 25: Benson siding station, about 50 feet north of barn near county road, 3½ miles east, 1½ miles south of Cle Elum and approximately 1,000 feet west-northwest of Benson siding on Milwaukee Railroad. Soil good, gentle southwest to northeast slope. Elevation 1,911 feet.

Station 26: Edgemont, 600 feet west, 1,200 feet north of southeast corner of sec. 33, T. 17 N., R. 19 E. Soil excellent. Very steep east-southeast to west-northwest slope, with station situated near bottom of a very narrow draw having a south to north slope. Elevation 1,700 feet.

Station 27: Edgar Larson place, near center of sec. 29, R. 20 E., T. 17 N. Shelter about 50 feet west of house, moderate southeast to northwest slope, soil good. Elevation 1,738 feet.

Station 28: Badger Creek station, 75 feet east of west side center of sec. 9, T. 16 N., R. 20 E. West side of section center is at road intersection. Station on bottom of pocket with local slope gentle southeast to northwest. Elevation 1,803 feet.

Station 29: Badger Pocket, 450 feet northwest of southeast corner of sec. 7, T. 16 N., R. 20 E. Station 15 feet north of ca,nal and 400 feet due west of road. Steep south-southwest to north-northeast slope, good soil. Elevation 2,100 feet.

Station 30: Ellensburg climatological station, 100 feet southeast of Kittitas County courthouse. Slope gentle north to south. Elevation 1,520 feet.

Station 31: Badger Pocket, 500 feet north of center of sec. 16, T. 16 N., R. 20 E. Exposure west of county road which joins Badger Creek road about 0.8 miles southeast from Aitken ranch. Moderate southwest to northeast slope, soil fair. Elevation 1,938 feet.

Station 32: Kern ranch in Park District. Station 50 feet northeast from house on south side of North Central Highway and about 9½ miles east from Ellensburg. Slight northeast to southwest slope with good soil. Elevation 2,005 feet.

Station 33: Don N. Smith farm 2 miles west of Thorp. Station situated on a bench from which there is a very gentle northwest to southeast slope, with lower benches to the north and east. Soil very good. Elevation 1,796 feet.

Station 34: Noll farm, 2.1 miles south-southeast of Thrall on Yakima paved highway. Station situated in a small pocket the bottom of which slopes gently from northeast to southwest, soil excellent. Elevation 1,493 feet.

Station 35: Diefenbacker farm, Edgemont, 3¼ miles east and one-half mile south of Thrall; station situated in bottom of rather extensive moderate draw, having a moderate south to north slope. Shelter 300 feet northeast of house. Soil excellent. Elevation 1,733 feet.

NOTES

During the course of the 5-year spring-temperature survey, it was expedient, due to the small number of instruments available for use in such a large area, to make occasional changes in the station locations. The changes made were as follows:

Twenty-five temperature survey stations were established at the beginning of the survey in March 1931.

Station 15 was discontinued April 17, 1931.

Station 26 was established April 17, 1931.

Stations 27, 28, and 29 were established March 24, 1932 on completion of construction of three new instrument shelters.

Station 13 was discontinued June 1, 1932.

Station 28 was discontinued June 1, 1932.

Stations 31 and 32 were established March 24, 1933.

Stations 12 and 32 were discontinued June 1, 1933.

Station 26 was discontinued June 1, 1933.

Stations 33, 34, and 35 were established March 22, 1934.

Station 30 is the regular United States Weather Bureau climatological station for Ellensburg with records throughout the year, covering the past 40 years.

Due to unavoidable circumstances it was necessary to make a change in the original location of the main key station (no. 1) at the beginning of the 1934 season. The previous location was in the Flynn orchard exactly one-fourth mile north from its new location. Topography and soil conditions are identical at the two locations.

Clearing and development of the new land necessitated moving stations 9 and 10 a few yards from their original locations. New locations are representative of the conditions at the original ones.

During the 1934 and 1935 seasons, readings for station no. 24 were made by Mr. Henry Roseburg, one-quarter mile north of original location, both locations representing the surrounding territory suitably.

TEMPERATURE SURVEY DATA

At the end of each spring season a mimeographed report was prepared, giving a detailed description of the season's weather, the locations of the various survey stations, minimum temperatures at all stations for all dates on which the temperature fell to 32° F. at any one station, the duration in hours and minutes of temperatures below 32° F. for each degree for each station, the complete 4:40 p. m. observational data at station 1, fruit tree blossoming dates, and average minimum temperatures at the various stations on nights with large and small temperature inversions. Copies of these detailed reports are available for reference at the central office of the Weather Bureau, Washington, D. C., at the headquarters station of the Weather Bureau Fruit-Frost Service, Pomona, Calif., and at the county courthouse and the chamber of commerce at Ellensburg. This paper is a summary of data contained in these five annual reports.

The temperature survey data can be correlated with the data from the Ellensburg cooperative station, which has a record going back more than 40 years, thus giving at least a fairly accurate picture of frost hazard and length of growing season at any one of the survey stations for any particular year. Temperature records at the Ellensburg station will be found in all the temperature survey tables except those showing temperature durations. An examination of the Ellensburg station data during the period of the survey and in previous years shows that the five survey springs were all warmer and more advanced than normal. This is brought out in figures 2 and 4.

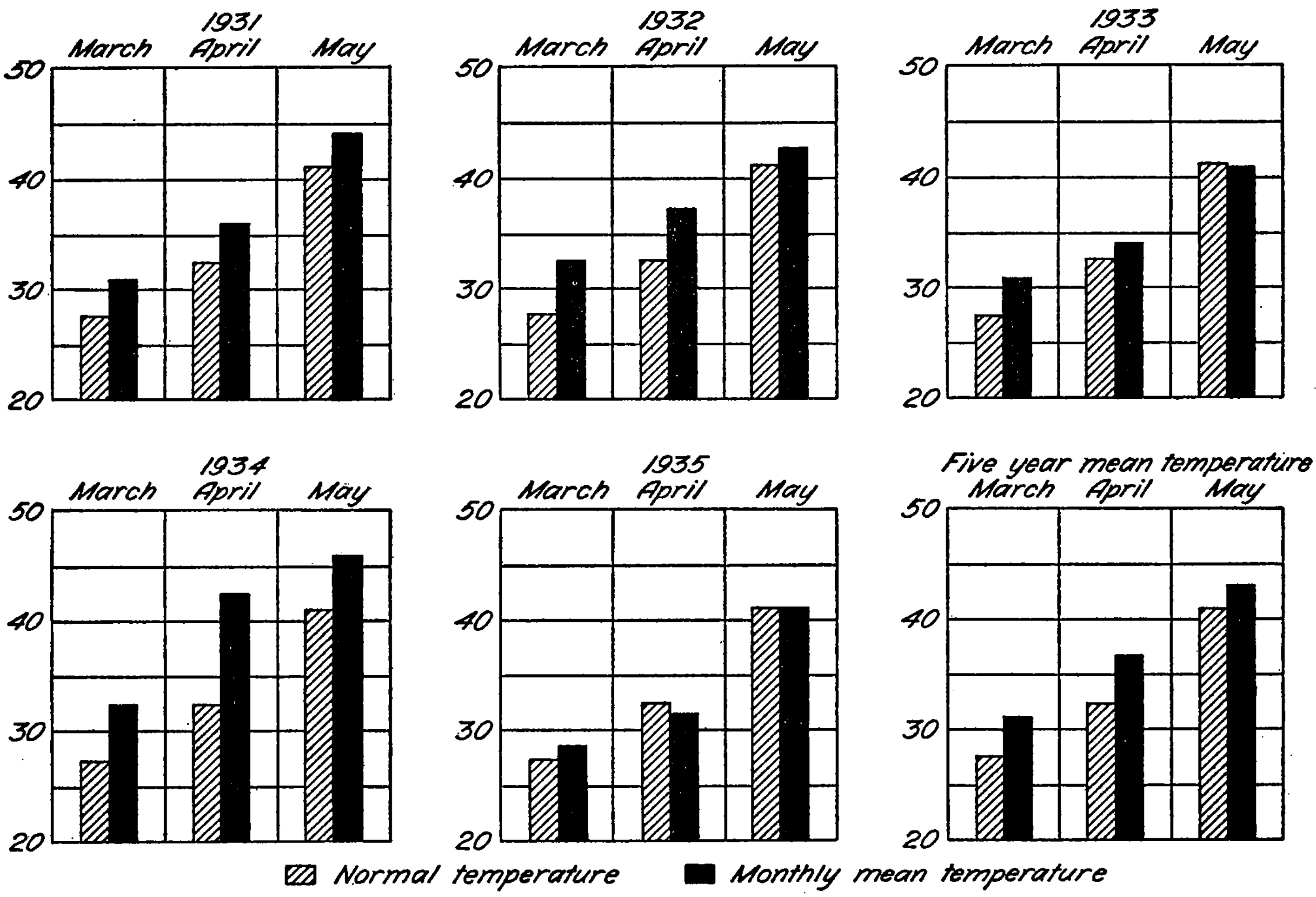

FIGURE 2.—Station 30, Ellensburg, Wash.: Climatological record of monthly minimum temperature and the normal for the spring months.

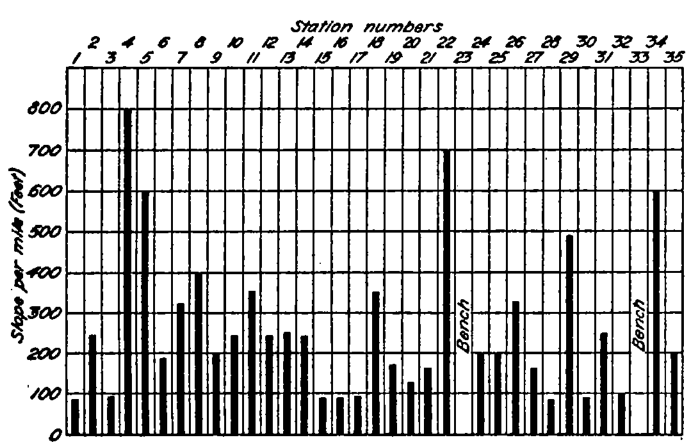

FIGURE 3.—Slope, in feet per mile, from each survey station.

During the 5-year period of the survey there were only two frosts which caused material commercial damage to apple crops. The first, on April 19, 1931, just as the apple buds had separated in the cluster, damaged a large percentage of the fruit buds, but due to the excess of bloom reduced the final crops only slightly. The second occurred on March 24, 1934, after 15 days of unseasonably warm weather during the middle of the month had caused rapid development of the buds. Temperatures on this latter date fell as low as 15° in the colder localities, and the apple crop was reduced by 15 to 25 percent in the old-established orchards in the most favorable locations.

The temperature survey was begun each year before any crops grown in the district had developed sufficiently to be susceptible to frost damage, in order to obtain more data to show temperature differences between different locations. The table of blossoming dates on page 164 shows the beginning of the frost season for apples, pears, and peas. As a general rule, crops grown in the district were not sufficiently advanced to be susceptible to frost damage before April 1.

WEATHER SUMMARY BY SEASONS

1931

The season was comparatively mild, with good growing weather and practically no precipitation during April and May. The night of May 19–20 was the last night with heavy frost. Frost on April 18, 19, and 20, with temperatures as low as 20° generally in colder locations damaged fruit blossoms considerably, but due to an excess of bloom, had little effect on the size of the final crop. The pea crop was set back by these cold nights, but no serious damage resulted.

1932

The 1932 season also was comparatively mild, with no seriously low temperatures after crops had advanced far enough to be damaged. There was good growing weather throughout the season, except during a cool period from April 15 to 25. Rainfall was much below normal.

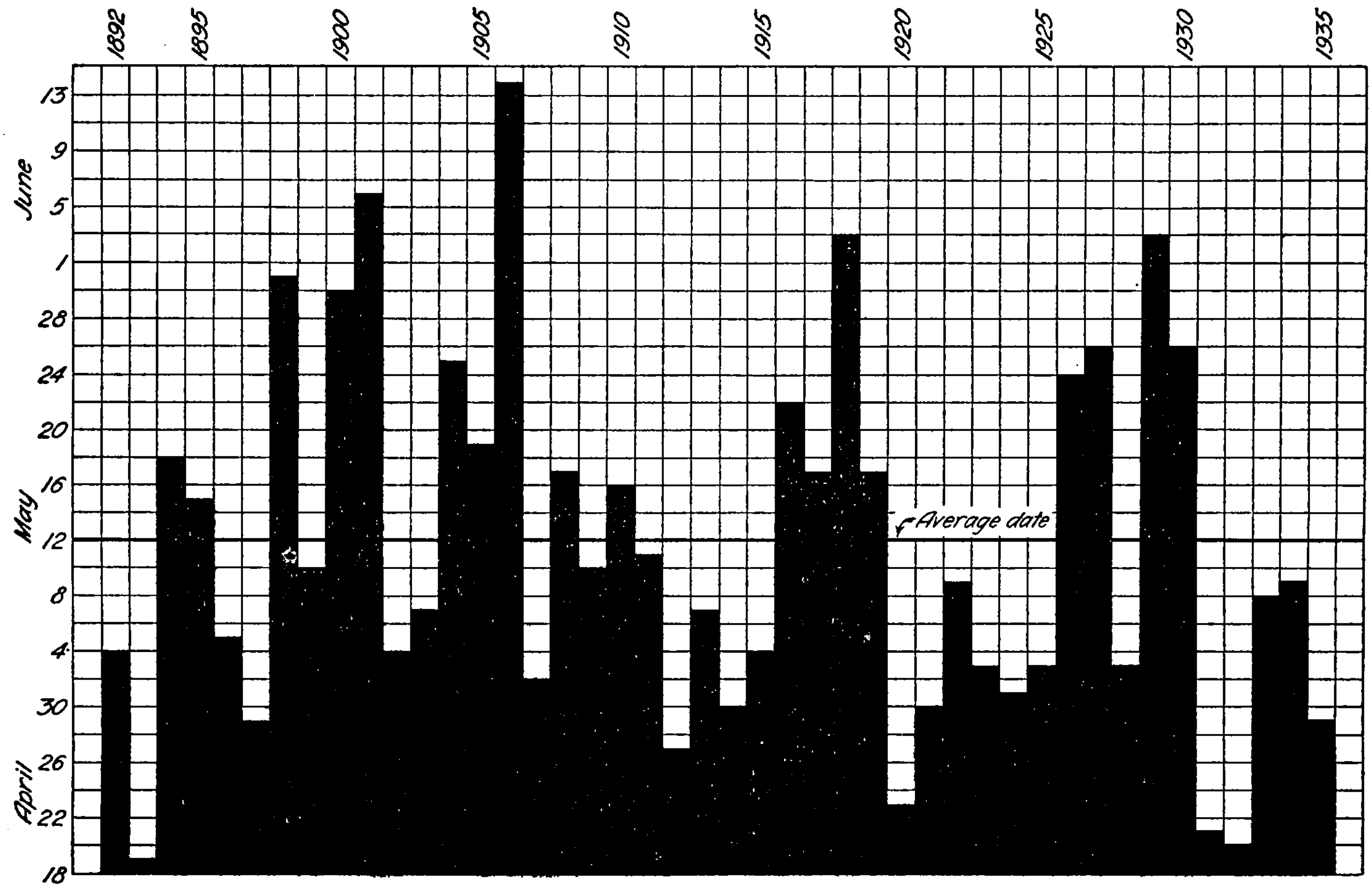

FIGURE 4.—Last date of killing frost in spring, Ellensburg, Wash., 1892-1935, inclusive; 43-year climatological record at station 30.

1933

Preceded by extremely low temperatures in February, the season continued cold and backward, with but one period of favorable growing weather, from April 21 to 30. At several stations the temperature fell to 20° on April 4 and 9. The last general heavy frost occurred on May 19, but frost on June 9 damaged truck crops considerably in scattered colder areas. There were frequent periods of light precipitation, but the total was less than normal.

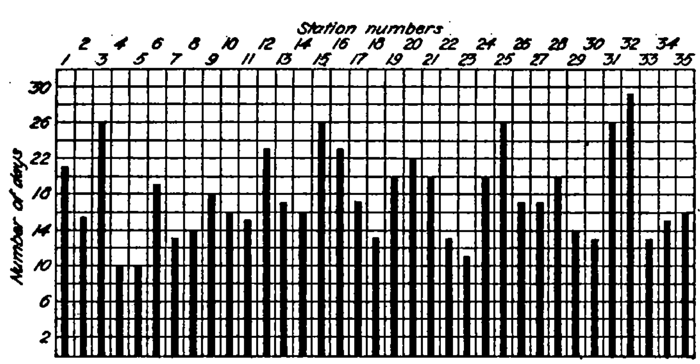

FIGURE 5.—Five-season average number of days 32°, or lower, recorded.

1934

Extremes of both high and low temperature occurred during this season. Temperatures were as low as 15° at some points on March 24, causing 15 to 25 percent damage to the apply crop in colder locations. One station registered 13.2° for a few minutes on this date. The last frost of the season occurred on May 21. During the latter part of April daytime temperatures were as high as 88 to 90° throughout the district, hastening crop growth considerably. A frost on May 9 caused slight damage to tender truck crops in the colder spots. There were 8 days with precipitation during the season and total precipitation was much below normal.

1935

This season was by far the coldest during the period of the survey, although the average minimum temperature at the Ellensburg cooperative climatological station was only slightly below the 28-year normal (fig. 2). Due to continued low day and night

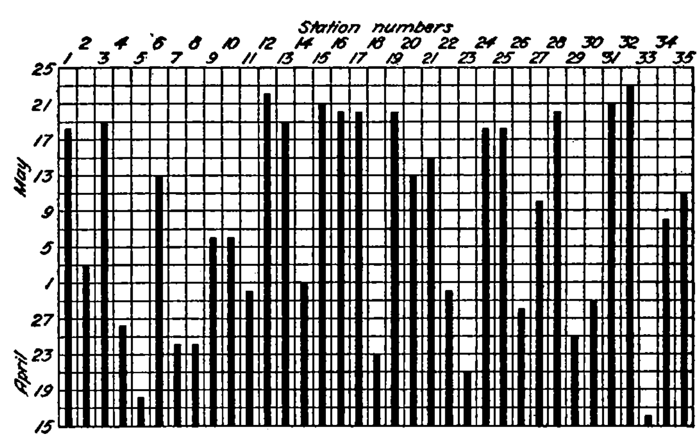

FIGURE 6.—Five-season average date last temperature 32°, or lower, occurred.

temperatures, accompanied by clouds and wind, crop growth was materially delayed. In some cases seed peas rotted in the ground, causing a considerable loss. April 2 was the coldest night at most of the survey stations, minimum temperatures ranging from 6.9° at the coldest station to 18° at the warmest, with many stations recording temperatures below 10°. Precipitation during the season was about one-fourth normal, the major portion falling in the form of snow on the night of March 24–25. At 9 a. m. on March 25 there was 2.9 inches of snow on the ground at Ellensburg.

Summary of blossoming dates, Edgemont district

	1931	1932	1933	1934	1935
D'Anjou pears in full bloom	May 2	May 4	May 2	Apr. 11	May 4
Jonathan apples in full bloom	May 10	May 15	May 16	Apr. 16	May 9
Early sweet peas in full bloom	June 15	June 10	June 14	June 13	June 11
Perfection peas in full bloom	June 20	June 26	June 30	June 30	June 27

NOTE.—Detailed fruit-blossoming records listed in seasonal reports.

The survey locations may be classified in three groups, each with fairly similar temperature characteristics. Group 1, comprising stations 4, 5, 7, 8, 18, 22, 23, 29, and 33, represents the most favorably located areas. Group 2, including stations 2, 9, 10, 11, 12, 13, 14, 17, 19, 21, 26, 27, 30, 34, and 35, is representative of the moderately favorable locations. Group 3, made up of stations 1, 3, 6, 15, 16, 20, 24, 25, 28, 31, and 32, is representative of areas with too high a frost hazard for the planting of any crops subject to damage by late spring low temperatures.

The total number of nights during the 5-year survey period on which temperatures of 32° or lower were

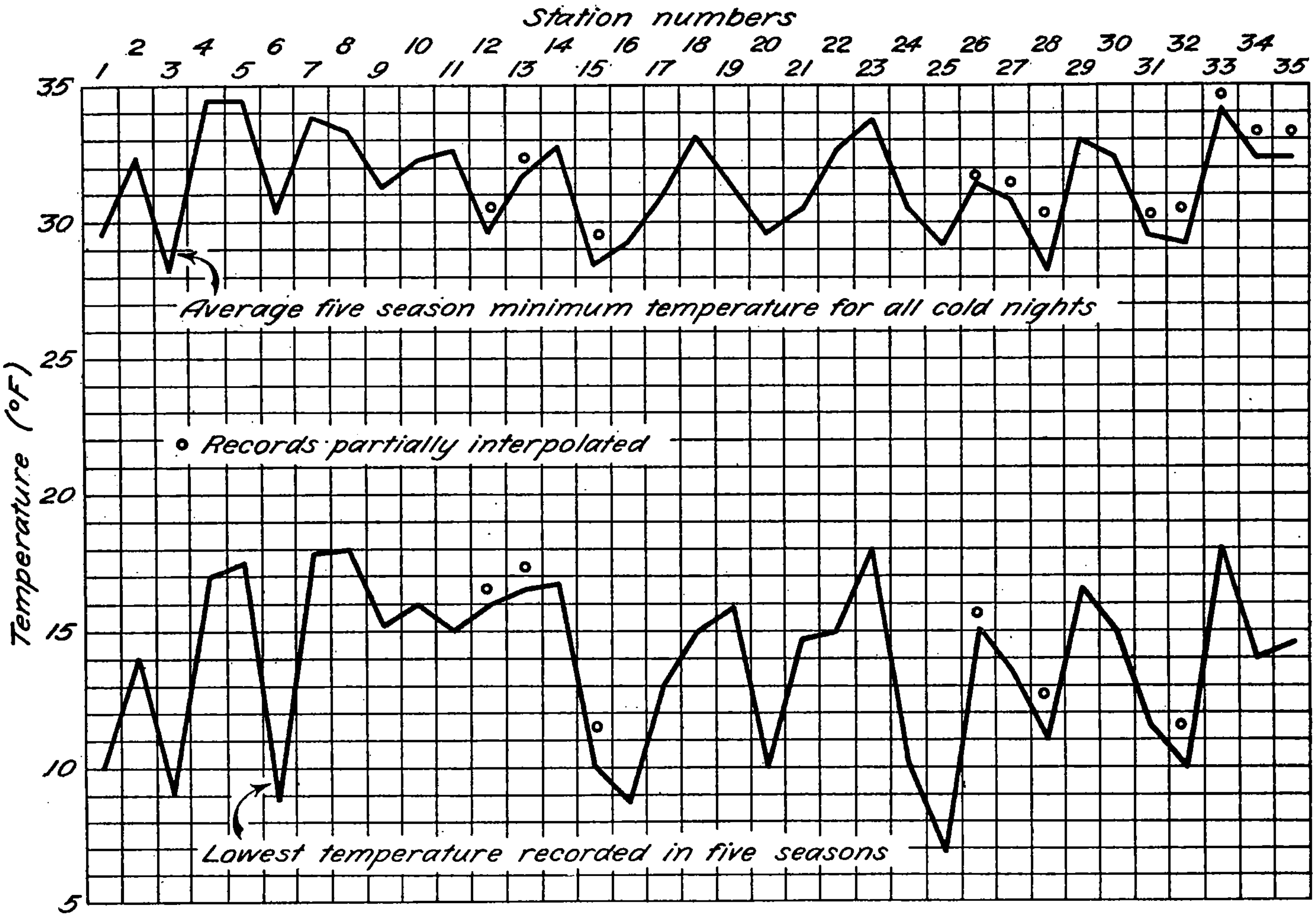

FIGURE 7.

GENERAL CONCLUSIONS

Because of the extremely broken topography of the survey area, with its isolated benches and steep slopes cut at frequent intervals by wide ravines, it is not practicable to draw isotherms to indicate temperature differences. However, knowing the locations of the survey stations, it should not be difficult for anyone to use the records on the ground to determine quite accurately what the relative frost hazard on any parcel of land in the district will be. Comparisons between the frost hazards at different localities can be made by referring to the tables and figures which form a part of this report, and to the topographic map. Descriptions of the locations and surrounding topography of the different stations are given on page 160.

registered at each station, together with the average number per season, are given in table 3. The average of 26 nights per season at station 3, when compared with the average of only 10 nights per season at station 5, only about a half mile distant, illustrates the large differences in minimum temperature on frosty spring nights that result from topographic influence. The average date on which the last temperature of 32° or lower was registered in spring is given for each station in figure 6. The difference between the earliest date, April 16 at station 33, and the latest date, May 23, at station 32, shows a growing season beginning more than a month earlier at station 33 than at station 32. Similar differences in temperature undoubtedly exist during the fall season, and the average annual growing season is probably more than 2 months longer at the former station than at the latter.

Before attempting to draw even general conclusions from the data, it probably will be well to discuss very briefly the two factors mainly responsible for the development of temperature differences in the district on clear nights in spring or fall, namely air drainage and wind. By air drainage is meant the draining, down hillsides to lower levels, of surface air which has been cooled through contact with the colder ground surface. On clear, calm nights the ground surface cools rapidly after sundown through radiation of heat. This radiation passes through the air without affecting its temperature materially, and the air itself cools more slowly because of its comparatively poor radiating qualities. Air in actual contact with the ground cools through conduction; but that a few feet above the ground, or out over the valley away from the hillside, changes temperature only slightly during the night, and is almost as warm at sunrise as it was at sunset. The surface air cooled through contact with the ground becomes denser than the warm air at the same level not in contact with the ground, and tends to drain away to lower levels, and to gather in depressions in somewhat the same manner as water. However, water drainage and air drainage are quite dissimilar in some respects, and air draining from a hillside or down a canyon should not be expected to behave in all respects in the same manner as water.[1]

Although relatively cold air drains slowly down even slightly sloping ground, its movement is so sluggish that the air which replaces it cools rapidly enough, through contact with the colder ground, to make the net effect of the drainage process almost negligible. In order for air drainage to be effective in retarding the temperature drop on a clear, calm night, the slope must be greater than 150 feet to the mile, and the steeper the slope the more effective is the air drainage process. (See fig. 3, showing slope at each station.) The coldest locations, of course, are those in depressions either inclosed or with outlets so small that the cold air drains into the depression faster than it can move out.

Elevation above sea level, or above the valley floor, does not in itself have any influence on the relative degree of frost hazard in nearby locations. A depression high up on the hillside, into which the cold air can drain faster than it moves out, may be fully as cold as a similar depression at the foot of the slope on a clear, calm night. Flat or well-rounded summits of low hills practically always are colder than steep slopes below on such nights.

The second factor of importance in determining temperature differences between slope and valley floor on clear nights is wind movement. Ideal conditions for air drainage are found only when there is no general air movement in the district; and even a light wind will interfere materially, through mixing the warm air above or away from the slopes with the thin stratum of surface air which has been cooled through contact with the ground. A moderate wind may prevent stratification entirely, both on the slopes and on the valley floor, and in such cases there may be little or no difference in temperature between the hills and valleys. There usually is more wind at higher elevations than on the valley floor, and at times the wind at higher levels may cause elevated benches to be considerably warmer than areas at lower elevations, where wind may be light or entirely lacking. In such cases higher bench temperatures are due entirely to prevention of temperature stratification by the mixing effect of the wind, and not to air drainage. After stratification has developed on the valley floor on a clear, calm night, a light puff of wind may cause the temperature of the surface air to rise several degrees in a few minutes, due to mixing of the cold air near the ground with the warmer air at moderate elevations.

It will be noted that the stations listed in group 1, the favorable locations, are situated either on moderate to steep slopes, or on benches above the valley floor. (See slopes, fig. 3.) On the slopes the higher minimum temperatures are due to both air drainage and the effects of the stronger breezes at higher elevations, while the higher temperatures on the benches are due almost entirely to wind. Stations in group 2 are located at moderate elevations and on moderate to gentle slopes; and those in group 3 on slightly sloping ground, usually at the base of a steeper slope or on nearly level ground on the valley floor.

In order to contrast the topography of the area surrounding station 28, one of the coldest places, with that in the vicinity of station 5, one of the warmest, a more detailed description of the locations of these two stations is given below.

Station no. 28 was located on the floor of Badger Pocket, a depression slightly more than 6 miles long, and

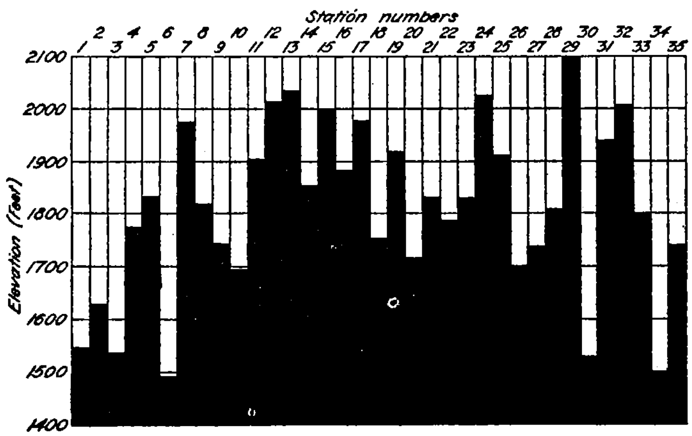

FIGURE 8.—Elevation of stations above mean sea level.

averaging about 1 mile wide, containing an irrigated area on the surrounding slopes about 4 miles wide at its mouth, narrowing to a width of about 1 mile at the upper closed end. The pocket floor slopes from southeast to northwest at the rate of from 60 to 100 feet to the mile. Extensive and comparatively steep slopes surround the pocket except at the open northwest end, where more nearly level land begins. Thus the area surrounding station 28 receives the air, cooled by nocturnal radiation, which drains from extensive slopes on three sides.

Station 5 was located in a different portion of the district, on a steep slope at a slightly higher elevation extending from south to north to much higher and lower elevations, the grade increasing considerably above, and decreasing slightly below the station location.

At times low temperatures in the survey district are the result of the general movement of cold air into the valley, accompanied by moderate to strong winds. In such cases air drainage is not a factor, and the higher slopes may be as cold as or colder than the valley floor. This condition, usually known as a freeze, seldom occurs in spring in the survey district, and the few freezes which occurred during the 5-year survey period came before crops had developed sufficiently to be damaged.

[1] W. J. Humphreys, Physics of the Air, second edition, pp. 154-157.

While it is not possible to describe in detail the relative frost hazard in every small area in the district, the following general summary may be used in conjunction with the tables and the topographic map which form a part of this report, to determine genera differences in frost hazard and length of growing season at any location within the survey area.

Of the 70,000 acres included in the survey, approximately 8,000 acres can be classed in group 1, the "favorable" locations. The Edgemont section, which lies above the 1,650-foot contour and extends eastward from Thrall to the latitude of the Wippel pumping plant, with its eastern portion narrowing under the pump lateral, and all other steep slopes on the eastern side of the valley above the 1,800-foot elevation, are included in this group. On the west and southwest sides of the district all moderately steep slopes above the west side canal also are included in group 1. The gently sloping elevated area 2 miles west of Thorp, extending southeastward, and the several benches along the river canyon in the northwest portion of the valley fall under the same favorable classification. East of Thorp and immediately across the river is an elevated area which also can be included in group 1. There is, however, a pocket in this area, the lower portion of which has only moderately favorable temperature conditions.

Group 2 includes about 22,000 acres with moderately favorable temperature conditions, lying for the most part on gently sloping ground immediately below the more favorably situated areas in group 1. The higher fourth of the north side of the valley is included in this group as well as the southern fourth of the Cle Elum area, although late frosts are more frequent in the latter section, and the growing season is somewhat shorter than in other portions of group 2.

Lands included in the temperature survey which were found to be least satisfactory from the standpoint of frost hazard and length of growing season, classed in group 3, include the lower elevations in Badger Pocket extending upward to the irrigation canals at the southeastern end of the pocket, even the highest portions having only a moderate slope. Group 3 also includes the small pocket bottom immediately east of the Milwaukee Railroad trestle across Johnson Creek Canyon. The Cle Elum area, with the exception of the higher and steeper slopes in the south quarter, has frequent late frosts, and is classed in group 3, as well as the lower portions of the north side of the district, including the Park area.

Small areas of only a few acres lying on steep slopes in the group described as unfavorable, or in pockets in the areas listed as favorable, must be excepted from the general classifications, but all of these can be picked out by inspection.

The intelligent use of the soil and temperature survey data now available for the newly irrigated portions of the valley should result in the planting of tender fruit and truck crops in the areas found to be most favorable, and the reservation of the most unfavorable portions of the district for the planting of grain and other crops requiring a relatively short growing season. The use of temperature survey data already has resulted in the selection of areas most favorable for the production of seed peas, and this new industry has shown an encouraging growth. A temperature survey of this type shows temperature differences which should continue to exist indefinitely, and the value of the data should be increasingly valuable in the years to come.

The authors wish to express their appreciation to Mr. Harold A. Rathbone, who prepared all the diagrams for this paper.

TABLE 1.—*Seasonal and 5-season absolute minimum * temperature with departures from stations nos. 2 and 3*

Station no.	1931			1932			1933			1934			1935		
	Minimum	Departure no. 2	Departure no. 3	Minimum	Departure no. 2	Departure no. 3	Minimum	Departure no. 2	Departure no. 3	Minimum	Departure no. 2	Departure no. 3	Minimum	Departure no. 2	Departure no. 3
1	21.1	−1.9	+1.7	23.7	−6.1	−0.3	20.5	−3.5	+5.0	15.0	−5.0	+1.8	10.0	−4.0	+1.0
2	23.0	0.0	+3.6	29.8	0.0	+5.8	24.0	0.0	+4.0	20.0	0.0	+6.8	14.0	0.0	+5.0
3	19.4	−3.6	0.0	24.0	−5.8	0.0	20.0	−4.0	0.0	13.2	−6.8	0.0	9.0	−5.0	0.0
4	24.3	+1.3	+4.9	30.6	+0.8	+6.6	26.0	+2.0	+6.0	24.6	+4.6	+11.4	17.0	+3.0	+8.0
5	23.3	+0.3	+3.9	30.9	+1.1	+6.9	28.8	+4.8	+8.8	24.7	+4.7	+11.5	17.5	+3.5	+8.5
6	22.7	−0.3	+3.3	27.0	−2.8	+3.0	21.0	−3.0	+1.0	15.6	−4.4	+2.4	8.9	−5.1	−0.1
7	22.0	−1.0	+2.6	29.0	−0.8	+5.0	25.8	+1.8	+5.8	26.0	+6.0	+12.8	17.8	+3.8	+8.8
8	22.0	−1.0	+2.6	29.5	−0.3	+5.5	26.0	+2.0	+6.0	24.9	+4.9	+11.7	18.0	+4.0	+9.0
9	22.1	−0.9	+2.7	26.2	−3.6	+2.2	23.0	−1.0	+3.0	20.2	+0.2	+7.0	15.3	+1.3	+6.3
10	21.3	−1.7	+1.9	28.0	−1.8	+4.0	25.0	+1.0	+5.0	21.0	+1.0	+7.8	16.0	+2.0	+7.0
11	22.0	−1.0	+2.6	28.5	−1.3	+4.5	25.5	+1.5	+5.5	22.1	+2.1	+8.9	15.0	+1.0	+6.0
12	20.0	−3.0	+0.6	27.1	−2.7	+3.1	19.6	−4.4	−0.4				ϕ 16.0	+2.0	+7.0
13	18.0	−5.0	−1.4	27.9	−1.9	+3.9							ϕ 16.5	+2.5	+7.5
14	24.1	+1.1	+4.7	27.0	−2.8	+3.0	26.0	+2.0	+6.0	24.0	+4.0	+10.8	16.6	+2.6	+7.6
15	‡ 19.2	−3.8	−0.2										ϕ 10.0	−4.0	+1.0
16	20.6	−2.4	+1.1	24.2	−4.6	+0.2	19.0	−5.0	−1.0	15.0	−5.0	+1.8	8.9	−5.1	−0.1
17	21.0	−2.0	+1.6	27.2	−2.6	+3.2	21.0	−3.0	+1.0	18.8	−1.2	+5.6	13.0	−1.0	+4.0
18	24.0	+1.0	+4.6	29.0	−0.8	+5.0	26.0	+2.0	+6.0	22.9	+2.9	+9.7	15.0	+1.0	+6.0
19	21.0	−2.0	+1.6	27.8	−2.0	+3.8	24.8	+0.8	+4.8	20.6	+0.6	+7.4	15.8	+1.8	+6.8
20	21.0	−2.0	+1.6	22.9	−6.9	−1.1	22.2	−1.8	+2.2	15.0	−5.0	+1.8	10.0	−4.0	+1.0
21	25.0	+2.0	+5.6	26.6	−3.2	+2.6	23.0	−1.0	+3.0	17.0	−3.0	+3.8	14.7	+0.7	+5.7
22	25.1	+2.1	+5.7	27.4	−2.4	+3.4	24.8	+0.8	+4.8	18.0	−2.0	+4.8	15.0	+1.0	+6.0
23	25.0	+2.0	+5.6	30.8	+1.0	+6.8	24.0	0.0	+4.0	23.6	+3.6	+10.4	18.0	+4.0	+9.0
24	22.5	−0.5	+3.1	26.5	−3.3	+2.5	22.2	−1.8	+2.2	18.9	−1.1	+5.7	10.1	−3.9	+1.1
25	19.5	−3.5	+0.1	26.0	−3.8	+2.0	21.7	−2.3	+1.7	17.5	−2.5	+4.3	6.9	−7.1	−2.1
26	‡ 23.6	+0.6	+4.2	27.0	−2.8	+3.0	23.1	−0.9	+3.1				ϕ 15.0	+1.0	+6.0
27				26.0	−3.8	+2.7	22.8	−1.2	+2.8	19.2	−0.8	+6.0	13.6	−0.4	+4.6
28				23.0	−6.8	−1.0							ϕ 11.0	−3.0	+2.0
29				28.0	−1.8	+4.0	23.2	−0.8	+3.2	24.2	+4.2	+11.0	16.5	+2.5	+7.5
30	25.0	+2.0	+5.6	28.0	−1.8	+4.0	24.0	0.0	+4.0	19.0	−1.0	+5.8	15.0	+1.0	+6.0
31							20.0	−4.0	0.0	17.0	−3.0	+3.8	11.5	−2.5	+2.5
32							19.1	−4.9	+0.9				ϕ 10.0	−4.0	+1.0
33										26.6	+6.6	+13.4	18.0	+4.0	+9.0
34										19.0	−1.0	+5.8	14.0	0.0	+5.0
35										19.0	−1.0	+5.8	14.5	+0.5	+5.5

*Absolute minimum for 5 years occurred during 1935 season.
‡ Incomplete record.
ϕ Record interpolated.

TABLE 2.—*Seasonal and 5-season average minimum temperature for all cold nights with departures from stations nos. 2 and 3*

Station no.	1931			1932			1933			1934			1935			5-year		
	Average	Departure no. 2	Departure no. 3	Average	Departure no. 2	Departure no. 3	Average	Departure no. 2	Departure no. 3	Average	Departure no. 2	Departure no. 3	Average	Departure no. 2	Departure no. 3	Average	Departure no. 2	Departure no. 3
1	31.2	−1.8	+2.4	31.4	−2.4	+1.5	27.8	−3.9	+0.1	29.3	−3.4	+1.2	28.5	−2.9	+2.7	29.6	−2.9	+1.5
2	33.0	0.0	+4.2	33.8	0.0	+3.9	31.7	0.0	+4.0	32.7	0.0	+4.6	31.4	0.0	+5.6	32.5	0.0	+4.4
3	28.8	−4.2	0.0	29.9	−3.9	0.0	27.7	−4.0	0.0	28.1	−4.6	0.0	25.8	−5.6	0.0	28.1	−4.4	0.0
4	34.6	+1.6	+5.8	35.7	+1.9	+5.8	33.1	+1.4	+5.4	35.5	+2.8	+7.4	33.2	+1.8	+7.4	34.4	+1.9	+6.3
5	35.2	+2.2	+6.4	33.6	−0.2	+3.7	34.2	+2.4	+6.5	35.8	+3.1	+7.7	33.2	+1.8	+7.4	34.4	+1.9	+6.3
6	32.3	−0.7	+3.5	32.6	−1.2	+2.7	29.3	−2.4	+1.6	29.0	−3.7	+0.9	28.1	−3.3	+2.3	30.3	−2.2	+2.1
7	35.1	+2.1	+6.3	34.6	+0.8	+4.7	32.2	+0.5	+4.5	35.4	+2.7	+7.3	31.8	+0.4	+6.0	33.8	+1.3	+5.7
8	33.2	+0.2	+4.4	34.7	+0.9	+4.8	32.3	+0.6	+4.6	34.3	+1.6	+6.2	32.2	+0.8	+6.4	33.3	+0.8	+5.2
9	32.2	−0.8	+3.4	32.4	−1.4	+2.5	27.9	−3.8	+0.2	32.4	−0.3	+4.3	30.6	−0.8	+4.8	31.1	−1.4	+3.0
10	32.8	−0.2	+4.0	33.8	0.0	+3.9	30.6	−1.1	+2.9	33.0	+0.3	+4.9	30.7	−0.7	+4.9	32.2	−0.3	+4.1
11	33.4	+0.4	+4.6	34.0	+0.2	+4.1	31.7	0.0	+4.0	33.3	+0.6	+5.2	31.0	−0.4	+5.2	32.7	+0.2	+4.6
12	31.1	−1.9	+2.3	31.6	−2.2	+1.7	27.6	−4.1	−0.1	*29.7	−3.0	+1.6	*28.0	−3.4	+2.2	*29.6	−2.9	+1.5
13	32.1	−0.9	+3.3	33.4	−0.4	+3.5	*30.6	−1.1	+2.9	*31.7	−1.0	+3.6	*30.0	−1.4	+4.2	*31.6	−0.9	+3.5
14	33.9	+0.9	+4.1	33.5	−0.3	+3.6	31.2	−0.5	+3.5	34.1	+1.4	+6.0	31.3	−0.1	+6.5	32.8	+0.3	+4.7
15	*29.4	−3.6	+0.6	*29.7	−4.1	−0.2	*27.5	−4.2	−0.2	*28.6	−4.1	+0.5	*26.9	−4.5	+1.1	*28.4	+4.1	+0.3
16	31.5	−1.5	+2.7	31.9	−1.9	+2.0	27.5	−4.2	−0.2	28.9	−3.8	+0.8	26.4	−5.0	+0.6	29.2	−3.3	+1.1
17	31.9	−1.1	+3.1	33.6	−0.2	+3.7	29.9	−1.8	+2.2	30.5	−2.2	+2.4	29.7	−1.7	+3.9	31.1	−1.4	+3.0
18	34.0	+1.0	+5.2	34.7	+0.9	+4.8	32.4	+0.7	+4.7	33.0	+0.3	+4.9	31.6	+0.2	+5.8	33.1	+0.6	+5.0
19	31.6	−1.4	+2.8	33.4	−0.4	+3.5	31.3	−0.4	+3.6	31.6	+1.1	+3.5	28.9	−2.5	+3.1	31.4	−1.1	+3.3
20	31.1	−1.9	+2.3	31.3	−2.5	+1.4	29.8	−1.9	+2.1	28.8	−3.9	+0.7	27.4	−4.0	+1.6	29.7	−2.8	+1.6
21	31.9	−1.1	+3.1	32.2	−1.6	+2.3	30.3	−1.4	+2.6	30.2	−2.5	+2.1	28.6	−2.8	+2.8	30.6	−1.9	+2.5
22	33.6	+0.6	+4.8	34.2	+0.4	+4.3	32.7	+1.0	+5.0	31.8	−0.9	+3.7	31.2	−0.2	+5.4	32.7	+0.2	+4.6
23	35.0	+2.0	+6.2	35.2	+1.4	+5.3	32.4	+0.7	+4.7	33.7	+1.0	+5.6	32.2	+0.8	+6.4	33.7	+1.2	+5.6
24	31.5	−1.5	+2.7	32.0	−1.8	+2.1	30.5	−1.2	+2.8	29.7	−3.0	+1.6	28.6	−2.8	+2.8	30.5	−2.0	+2.4
25	29.1	−3.9	+0.3	31.2	−2.6	+1.3	28.5	−3.2	+0.8	29.3	+3.4	+1.2	27.5	−3.9	+1.7	29.1	−3.4	+1.0
26	*31.7	−1.3	+2.9	32.7	−1.1	+2.8	30.7	−1.0	+3.0	*31.5	−1.2	+3.4	*30.0	−1.4	+4.2	*31.3	−1.2	+3.2
27	*31.5	−1.5	+2.7	32.1	−1.7	+2.2	29.6	−2.1	+1.9	32.2	−0.5	+4.1	29.7	−1.7	+3.9	30.9	−1.6	+2.8
28	*29.1	−3.9	+0.3	29.4	−4.4	−0.5	*27.2	−4.5	−0.5	*28.3	−3.4	+0.2	*26.8	−4.6	+1.0	*28.2	−4.3	+0.1
29	*31.0	−2.0	+2.2	34.4	+0.6	+4.5	30.8	−0.9	+3.1	34.3	+1.6	+6.2	32.4	+1.0	+6.6	33.0	+0.5	+4.9
30	33.0	0.0	+4.2	34.2	+0.4	+4.3	31.7	0.0	+4.0	32.1	−0.6	+4.0	31.5	+0.1	+5.7	32.5	0.0	+4.4
31	*30.1	−2.9	+1.3	*30.4	−3.4	+0.5	28.2	−3.5	+0.5	30.5	−2.2	+2.4	27.6	−3.8	+1.8	*29.4	−3.1	+1.3
32	*30.0	−3.0	+1.2	*30.3	−3.5	+0.4	28.1	−3.6	+0.4	*29.2	−3.5	+1.1	*28.5	−2.9	+2.7	*29.2	−3.3	+1.1
33	*35.0	+2.0	+6.2	*35.3	+1.5	+5.4	*33.0	+1.3	+5.3	35.3	+2.6	+7.2	32.2	+0.8	+6.5	*34.2	+1.7	+6.1
34	*33.3	+0.3	+4.5	*33.7	−0.1	+3.8	*31.3	−0.4	+3.6	32.6	−0.1	+4.5	30.6	−0.8	+4.8	*32.3	−0.2	+4.2
35	*33.1	+0.1	+4.3	*33.5	−0.3	+3.6	*31.5	−0.2	+3.8	32.6	−0.1	+4.5	30.6	−0.8	+4.8	*32.3	−0.2	+4.2

* Record interpolated.

TABLE 3.—*Seasonal and 5-year frequency of temperatures 32° or lower*

Station number	5-year average	Number of days 32° or lower occurred					
		1931	1932	1933	1934	1935	5-year total
1	21	18	19	24	14	30	105
2	15	16	10	19	7	25	77
3	26	28	19	28	16	38	129
4	10	12	2	14	4	17	49
5	10	10	3	12	5	21	51
6	19	18	11	22	13	33	97
7	13	15	8	16	4	23	66
8	14	15	9	17	5	22	68
9	18	19	13	23	6	28	84
10	16	17	10	21	7	27	82
11	15	16	8	19	6	27	76
12	23	22	17	28	*16	*33	116
13	17	18	17	*11	*10	*27	83
14	16	15	13	22	5	23	78
15	26	*26	*29	*20	*19	*36	130
16	23	17	14	28	14	41	114
17	17	17	8	21	10	27	83
18	13	13	6	17	7	24	67
19	20	22	13	22	8	33	98
20	22	20	19	21	14	36	110
21	20	16	18	21	12	35	102
22	13	11	8	15	7	23	64
23	11	10	2	17	6	22	57
24	20	17	14	21	16	32	100
25	26	27	20	30	16	36	129
26	17	*17	11	20	*10	*27	85
27	17	*14	15	24	6	28	87
28	20	*20	23	*14	*13	*30	100
29	14	*17	9	19	5	20	70
30	13	14	7	17	7	21	66
31	26	*26	*29	27	11	37	130
32	29	*27	*35	29	*19	*37	147
33	13	*14	*16	*8	6	22	66
34	15	*15	*18	*9	7	26	75
35	16	*16	*19	*10	8	27	80

*Record interpolated.

TABLE 4.—*Number of hours temperature was 32° and lower by seasons*

Station number	1931		1932		1933		1934		1935		Total		Grand total	5-year average
	April	May	April	May	April	May	April	May	April	May	April	May		
1	69	1	-	-	-	-	-	-	112	7	*310	*80	390	78
2	54	0	19	0	61	6	8	1	79	1	221	8	229	46
3	98	9	59	2	98	35	19	10	144	28	418	84	502	100
4	30	0	2	0	50	0	3	0	55	0	140	0	140	28
5	20	0	2	0	46	0	3	0	62	0	133	0	133	27
6	49	1	21	1	76	17	11	9	116	6	273	34	307	61
7	38	0	18	0	61	0	7	0	70	1	194	1	195	39
8	51	0	15	0	57	0	7	0	67	2	197	2	199	40
9	68	1	35	0	70	12	13	0	-	-	*220	*14	234	47
10	52	0	21	0	74	10	11	0	88	3	246	13	259	52
11	40	0	23	0	66	5	13	0	85	8	227	13	240	48
12	70	5	51	4	117	34	-	-	-	-	*310	*85	395	79
13	60	2	42	1	-	-	-	-	-	-	*330	*90	420	84
14	52	0	-	-	-	-	10	0	81	0	*220	*7	227	45
15	-	-	-	-	-	-	-	-	-	-	*315	*90	405	81
16	52	6	30	8	110	28	15	13	119	33	326	92	418	84
17	49	1	13	3	77	10	8	8	94	2	241	24	265	53
18	37	0	11	0	58	2	4	0	70	0	180	2	182	36
19	57	4	20	3	71	18	9	4	107	5	164	34	198	40
20	76	0	23	2	66	14	8	5	121	3	294	24	318	64
21	35	0	22	3	63	11	8	6	92	6	220	26	246	49
22	28	0	8	0	38	4	6	1	81	0	161	5	166	33
23	29	0	3	0	47	7	4	0	86	0	169	7	176	35
24	75	0	36	6	91	5	-	-	-	-	*325	*40	365	73
25	94	9	-	-	-	-	-	-	-	-	*400	*85	485	97
26	-	5	34	0	71	10	-	-	-	-	*220	*15	235	47
27	-	-	37	0	106	20	12	2	110	7	*230	*30	260	52
28	-	-	56	13	-	-	-	-	-	-	*420	*95	515	103
29	-	-	22	0	81	4	13	0	66	2	*170	*5	175	35
30	-	-	-	-	-	-	-	-	-	-	*200	*5	205	41
31	-	-	-	-	91	29	17	7	131	25	*400	*60	460	92
32	-	-	-	-	-	-	-	-	-	-	*400	*55	455	91
33	-	-	-	-	-	-	3	0	-	-	*135	*0	135	27
34	-	-	-	-	-	-	5	1	88	7	*160	*2	162	32
35	-	-	-	-	-	-	11	0	91	4	*190	*2	192	38

* Record interpolated.

Records for March not considered in above table.

TABLE 5.—*Number of hours temperature was 29° and lower by seasons*

Station no.	1931		1932		1933		1934		1935		Total		Grand total	5-year average
	April	May	April	May	April	May	April	May	April	May	April	May		
1	36	0	----	----	----	----	----	----	83	0	*200	*20	220	44
2	17	0	0	0	30	0	1	0	39	0	86	0	86	17
3	66	1	26	0	72	12	6	0	45	10	215	23	238	48
4	5	0	0	0	15	0	0	0	34	0	54	0	54	11
5	2	0	0	0	2	0	0	0	34	0	38	0	38	8
6	21	0	4	0	40	5	5	0	78	0	148	5	153	31
7	8	0	1	0	17	0	0	0	44	0	70	0	70	14
8	20	0	0	0	18	0	0	0	35	0	73	0	73	15
9	39	0	17	0	42	3	1	0	----	----	*110	*2	112	22
10	16	0	3	0	40	2	2	0	44	0	105	2	107	21
11	13	0	2	0	21	0	4	0	49	0	89	0	89	18
12	33	0	21	0	78	6	----	----	----	----	*208	*21	229	46
13	19	0	9	0	----	----	----	----	----	----	*200	*15	215	43
14	14	0	----	----	----	----	0	0	41	0	*103	*2	105	21
15	----	----	----	----	----	----	----	----	----	----	*210	*22	232	46
16	25	0	11	0	75	10	6	0	86	10	203	20	223	45
17	22	0	3	0	45	2	4	0	67	0	141	2	143	29
18	5	0	0	0	17	0	0	0	38	0	60	0	60	12
19	22	0	4	0	34	0	4	0	66	0	130	0	130	26
20	32	0	11	0	32	6	4	0	87	0	167	6	173	35

TABLE 5.—*Number of hours temperature was 29° and lower by seasons*—Continued

Station No.	1931		1932		1933		1934		1935		Total		Grand total	5-year average
	April	May	April	May	April	May	April	May	April	May	April	May		
21	16	0	4	0	36	0	5	0	67	0	128	0	128	26
22	10	0	2	0	9	2	5	0	51	0	77	2	79	16
23	10	0	0	0	12	1	0	0	46	0	68	1	69	14
24	40	0	6	0	35	0	----	----	----	----	*115	*4	119	24
25	64	3	----	----	----	----	----	----	----	----	*220	*25	245	49
26	----	1	5	0	34	0	----	----	----	----	*148	*5	153	31
27	----	----	11	0	52	5	4	0	56	0	*161	*2	163	33
28	----	----	34	0	0	----	----	----	----	----	*230	*30	260	52
29	----	----	2	0	51	0	2	0	38	0	*105	*0	105	21
30	----	----	----	----	----	----	----	----	----	----	*85	*0	85	17
31	----	----	----	----	64	6	10	0	84	10	*220	*20	240	48
32	----	----	----	----	----	----	----	----	----	----	*230	*30	260	52
33	----	----	----	----	----	----	0	0	----	----	*65	*0	65	13
34	----	----	----	----	----	----	2	0	46	0	*100	*1	101	20
35	----	----	----	----	----	----	0	0	46	0	*100	*1	101	20

*Record interpolated.

Records for the month of March not included in above table.

TORNADO DISASTERS IN THE SOUTHEASTERN STATES, APRIL 1936

By J. B. KINCER

[Weather Bureau, Washington, June 1936]

During the first week of April 1936, two series of disastrous tornadoes occurred in several Southeastern States, the first on April 1–2 and the second on April 5–6. In the first series tornadic storms were reported from 7 cities or towns in Georgia and the Carolinas; in the second the storms were of greater geographic extent, occurring at 17 different places scattered through 6 States, including Arkansas, Tennessee, Mississippi, Alabama, Georgia, and South Carolina. Figure 1 shows the places where tornadoes were reported and the approximate time of the several occurrences.

The atmospheric conditions responsible for these disastrous storms, as shown by the daily synoptic weather maps, are described by Louis P. Harrison, Weather Bureau, Washington, D. C., as follows:

"The two series of storms had their genesis in two different energetic depressions of rather similar nature, each characterized by V-shaped isobars with a trough extending in a south to southwesterly direction, quickly followed by an extensive anticyclone of pronounced high pressure. The tornadoes occurred in connection with the cold fronts which were associated with the troughs of these depressions and passed over the region under consideration during the periods April 1–2, and April 5–6, respectively.

"In each case the front marked the juncture of rather cold, dry, Polar Continental air, overlain in part by Polar Pacific air, advancing southeastward against warm, moist, tropical air, largely from the Gulf of Mexico. These circumstances produced conditions peculiarly favorable for the development of violent local disturbances both of the tornadic and thunderstorm variety, for there existed not only large horizontal temperature gradients across the front, but also remarkably strong vertical gradients through 2 to 5 or more kilometers in the cold-air mass."

The following accounts and descriptions of the storms are based largely on reports by the several Weather Bureau section directors of the States named:

FIRST SERIES, APRIL 1–2, 1936

In this series the first tornado was reported near Tignall, Ga., about 8:30 p. m., April 1, moving in a northeasterly direction. A number of buildings were ruined, numerous farm animals killed, and at least one person badly injured. The second is reported as occurring about 30 minutes later, at Lincolnton, Ga., some 17 miles southeast of Tignall, moving in a southeasterly direction. The telltale funnel-shaped cloud was reported, and also a rotary wind movement was evident from the position of felled trees. Reports made by the Lincolnton postmaster indicate that about 50 houses were more or less wrecked, but no satisfactory estimate of actual property loss is available. From the description of the movement and time of occurrence of the storm, and the relative geographic location of Tignall to Lincolnton, there were evidently two separate storms in this case.

The next reported occurrence was early the following morning, about 6 a. m., April 2, at Sasser, Ga. This storm moved in a northeastward direction over a path of unknown length, with destructive effects over an area from 200 to 500 yards in width; rotary wind action was evident from the position of the trees overthrown. One Negro man was killed, several people injured, and the property damage was estimated at about $3,000. The next storm, at Leesburg, Ga., about 10 miles east of Sasser, was reported to have occurred an hour later, or about 7 a. m. Here, eight people were injured and one Negro man killed; property loss was estimated at $4,300. At 7:30 a. m. of the same day, or half an hour after Leesburg was visited, an exceedingly destructive tornado occurred at Cordele, Ga., in which 23 persons were killed, nearly 500 injured, and property damaged to the amount of $3,000,000. In addition to the heavy loss of life, the property destruction here was appalling; 287 buildings were demolished, of which 100 were among the best residential homes in the city. Many of the finest houses were torn to splinters, as if blown up by great charges of dynamite.

From the locations of Sasser, Leesburg, and Cordele, and the time of tornado occurrence in each, it is quite likely that the same storm passed through these localities in succession. The time reported at Sasser, or at Leesburg, about 10 miles apart, may not have been accurately given; the first reported "about 6 a. m." and the latter "about 7 a. m."

About an hour after the Cordele disaster, or at 8:30 a. m., a tornado occurred near Lodge, Colleton County,